REMARKS

Upon entry of the Amendment, Claims 22-34 will be pending in the application.

Claims 23 is amended to recite "a $GaN_{1-X}P_X$ $(0<X<1)$ single crystal lower clad layer as a mixed crystal of gallium nitride (GaN) and gallium phosphide (GaP), the phosphorous compositional ratio (X) of the $GaN_{1-X}P_X$ lower clad layer is set to obtain the lattice matching with the BP-based buffer layer, a $Ga_YIn_{1-Y}N$ ~~$(0.9\leq Y\leq 1)$~~ $(0\leq Y\leq 1)$ light-emitting layer", and Claim 29 is amended similarly to recite "a $GaN_{1-X}P_X$ $(0<X<1)$ single crystal lower clad layer as a mixed crystal of gallium nitride (GaN) and gallium phosphide (GaP), a $Ga_YIn_{1-Y}N$ ~~$(0.9\leq Y\leq 1)$~~ $(0\leq Y\leq 1)$ light-emitting layer". Support can be found, for example, at original Claims 23 and 29 and at page 7, lines 31-33 of the specification as originally filed. No new matter is added.

New Claims 33-34 are added. Support can be found, for example, at page 6, lines 19-25 and in the paragraph bridging pages 16-17, respectively, of the specification as originally filed. No new matter is added.

Entry of the Amendment is respectfully requested along with reconsideration and review of the claims on the merits.

Statement of Summary of Examiner's Interview

Applicant and Applicant's representative kindly thank the Examiner for the time spent conducting a telephonic Examiner's Interview on November 1, 2005. Applicant proposed the same claim amendments to Claim 23 and 29 as viewed in the Amendments to the Claims. Such claim amendments were discussed as being a combination of features not disclosed or taught in

the cited references. However, the Examiner did not take a position for patentability of amended Claims 23 and 29 over Terashima and Ishida, indicating that further investigation and search would still be necessary upon the filing of the present Amendment.

Allowable Subject Matter

Applicant appreciates the Examiner's indication of allowance of Claims 22, 28 and 30 are allowed, directed to a single hetero-junction device including a GaInN light-emitting layer and a GaNP lower clad layer.

Claim Rejection - 35 U.S.C. § 112

Claims 23-27, 29, 31 and 32 are rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. In particular, the Examiner asserts that the claimed range of $0.9 \leq Y \leq 1$ for the stoichiometric parameter Y does not find support in the specification.

Applicant responds as follows.

Without conceding the merit of the rejection, Applicant amends Claims 23 and 29 to recite the original claimed range of $0 \leq Y \leq 1$.

Accordingly, Applicant respectfully requests reconsideration and withdrawal of the rejection under 35 U.S.C. § 112, first paragraph.

Claim Rejections - 35 U.S.C. §103

A. Claims 23-27, 29 and 31 are rejected under 35 U.S.C. §103(a) as being

unpatentable over Terashima et al (U.S. Pat. No. 6,069,021) in view of Ishida et al (U.S. Pat. No. 6,339,014).

In addition to the Examiner's previous remarks, the Examiner also cites Terashima et al as disclosing a $Ga_YIn_{1-Y}N$ ($0.9 \leq Y \leq 1$) light emitting layer 105, where Y=0.98 (citing col. 14, line 65 - col. 15, line 3).

The Examiner still recognizes that Terashima et al does not teach the lower clad layer to be a $GaN_{1-x}P_x$ lower clad layer instead of a $GaN_{1-x}As_x$ lower clad layer, because Terashima et al teaches doping the GaN layer with As. However, the Examiner maintains that it would have been obvious to use P instead of As for doping in view of Ishida et al, which is cited for teaching at least the equivalence of using P rather than As for the growing of n-type GaN layers. The Examiner maintains that given the use of P-doping in a prior step in Terashima et al, namely in the formation of the buffer layer, it would have assertedly been obvious to use the same dopant P, thus obviating the need for additional complexity in the manufacturing process, while the lattice matching achieved by selecting As as taught by Terashima et al and selecting x could have been equally straightforwardly achieved through doping with P (phosphorous).

The Examiner states that the motivation to replace As with P derives at least from the economic saving of using the P source already in use for the process of making the buffer layer in the device by Terashima instead of having to use the As source, and in addition from the obvious toxic nature of As.

B. Claim 32 is rejected under 35 U.S.C. §103(a) as being unpatentable over Terashima et al and Ishida et al as applied to Claim 23, and further in view of Prior Art as

Admitted by Applicant. Particularly, the Examiner asserts that MOCVD is known to produce a GaN based light-emitting layer as a single crystal except in the absence of lattice matching to an underlying substrate.

Applicant responds as follows.

As previously noted, Claim 23 (and Claim 29 is amended in a similar manner) is amended to recite "a $GaN_{1-X}P_X$ (0<X<1) single crystal lower clad layer as a mixed crystal of gallium nitride (GaN) and gallium phosphide (GaP)".

In the present invention, a $GaN_{1-X}P_X$ (wherein 0<X<1) single crystal lower clad layer as a mixed crystal of GaN and GaP is stacked via the buffer layer comprising a BP-based material, because by adjusting the phosphorus compositional ratio (X) of $GaN_{1-X}P_X$ (wherein 0<X<1), lattice matching with the BP-based material constituting the buffer layer can be attained. Therefore, a single crystal layer having excellent crystallinity can be obtained (see paragraph bridging pages 7-8).

GaN single crystal and GaP single crystal are mixed, and GaNP crystalline solid solution is formed. The structure of GaNP is the structure which replaced a part of P in the structure of GaP to N. (Or the structure which replaced a part of N in the structure of GaN to P.) Applicant kindly directs the Examiner to the enclosed figure (for reference only) for a visual description of a "GaNP mixed crystal". Thus, GaNP is a single crystal. Applicant also kindly directs the Examiner to the enclosed section 5.3 of "HETEROSTRUCTURE LASERS" describing "crystalline solid solutions".

Applicant traverses the obviousness rejection on the basis that Terashima in view of Ishida fails to render obvious the combined features of the present invention.

Terashima teaches doping a GaN lower clad layer with As to form a GaNAs layer. Terashima only discloses phosphorus in PCl_3 as a source of phosphorus in forming Terashima's buffer layer. However, Terashima fails to disclose or teach a single crystal lower clad layer as a mixed crystal of GaN and GaP.

Ishida fails to make up for Terashima's deficiencies. Ishida teaches doping the n-type GaN layer with As or P. The element As or P is an impurity atom in the n-type GaN layer which can accept or take up one or more electrons from the crystal and become negatively charged. Ishida's disclosure of As or P fails to disclose a mixed crystal according to the present invention.

Dependent Claims 24-27 and 31-32 are patentable for at least the same reasons given above.

Accordingly, Applicant respectfully requests reconsideration and withdrawal of the obviousness rejections.

Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

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23373
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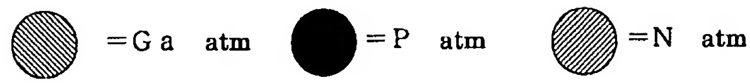
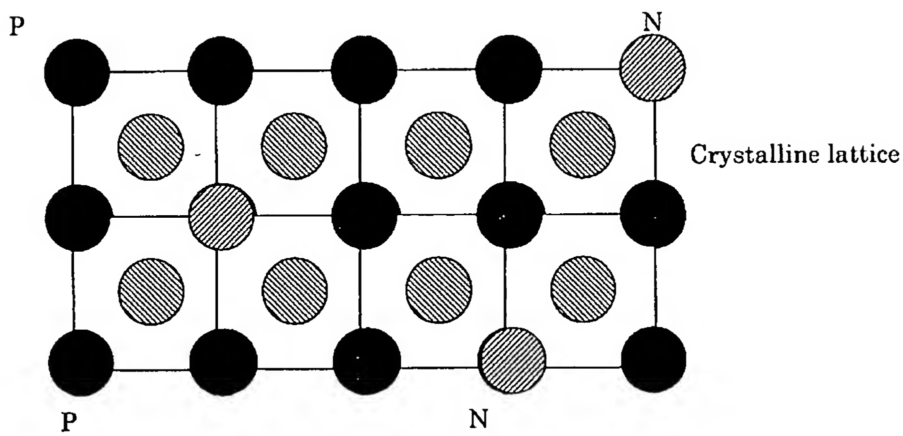
Date: November 8, 2005

"GaNP" mixed crystal



P (phosphorus) atoms are partially replaced with N (nitrogen) atoms. ← "mixed crystal"



QUANTUM ELECTRONICS — PRINCIPLES AND APPLICATIONS

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In preparation

Robert K. Erf (Ed.). SPECKLE METROLOGY

HETEROSTRUCTURE LASERS

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PART B

Materials and Operating Characteristics

ACADEMIC PRESS New York San Francisco London 1978
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5.3 III–V TERNARY SOLID SOLUTIONS

Crystalline Solid Solutions

When compounds are formed that have more than one group III element distributed randomly on group III lattice sites or more than one group V element distributed randomly on group V lattice sites, those compounds are crystalline solid solutions. As described in Chapter 1, the notation most frequently used, and used throughout this book, is $A_xB_{1-x}C_yD_{1-y}$ with A and B for the group III elements and with C and D for the group V elements. If A, B, and C are group III elements and D is a group V element, the notation $(A_xB_{1-x})_yC_{1-y}D$ is convenient. A similar notation is used for the solid solution with three group V elements and one group III element. If solid solutions with all values of x or y between 0 and 1 can exist, the system is said to consist of a complete series of solid solutions. This is a condition that occurs for a number of III–V systems. Phase and thermodynamic studies suggest that the tendency towards unmixing, i.e., a limiting of the possible range of x and y to less than 0 to 1, increases with increasing difference in the covalent radii of the different atoms occupying the same set of lattice sites.

In ternary III–V solid solutions, the lattice constant of the crystal generally scales linearly with composition (Vegard's law), and this behavior can be reasonably assumed to occur also for the quaternary solid solutions. Linear variation with composition does not, in general, occur for the other properties. However, when detailed data are unavailable, it is often necessary to use linear interpolation.

The variation of E_g with composition is the primary property of interest when considering heterojunctions. As illustrated in Chapter 4, not only is the energy difference from the valence band to the lowest lying conduction band important, but the energy separating the various conduction band minima can influence heterostructure laser performance. Therefore, it is useful to know the compositional dependence of the Γ, L, and X conduction-band minima. There are 18 conceivable ternary systems among the group III and group V elements of interest, and experimental data are available for more than half of these. For most of the rest, it is likely that extensive solid solutions do not exist. The energy-gap compositional dependence often can be represented by

$$E_g = a + bx + cx^2 \qquad (5.3\text{-}1)$$

for the ternary solid solution $A_xB_{1-x}C$ or AC_yD_{1-y}. The bowing parameter c has been treated theoretically by Van Vechten and Bergstresser.[17] Their theory may be used to estimate c when experimental data are unavailable.

The available experimental compositional dependence of E_g in the ternary solid solutions is summarized in this section.

Because no data are available for the ternaries, properties such as electron affinity and dielectric constant that were given in Table 5.2-3 for III–V binaries are taken to have a linear compositional dependence. The effective mass, however, can have a quadratic dependence on composition.[18] Depending on the system, the bowing parameter can be small so that the more convenient linear dependence may be used.

The compositional dependence of the refractive index has been determined for only a few of these ternary systems. The refractive index for $Al_xGa_{1-x}As$ has been measured over the composition range of interest for heterostructure lasers[19] and was summarized in Figs. 2.5-4 and 2.5-5. Data has also been obtained for GaP_xAs_{1-x}.[20,21] Afromowitz[22] used a modification of the semi-empirical single-effective-oscillator model[23] to include an approximation of the absorption spectrum and evaluated $\bar{n}$ as a function of x for photon energies less than E_g for $Al_xGa_{1-x}As$, GaP_xAs_{1-x}, and $Ga_xIn_{1-x}P$. These models in Refs. 22 and 23 can be useful for the calculation of $\bar{n}$ as a function of E for systems where no experimental data are available.

The thermal conductivity in the ternary solid solution is generally a minimum near $x = 0.50$.[16,24] For $Al_xGa_{1-x}As$, the thermal conductivity decreases from the binary values by a factor of four when x is between 0.4 and 0.6.[24] This behavior means that the thermal resistance is more of a problem in the ternaries than in the binary compounds. Additional properties of the III–V ternary solid solutions may be found in the compilation by Neuberger.[25] The next part of this section presents many of the available E_g versus x diagrams for the III–V ternary solid solutions. An earlier compilation was given by Onton.[26]

$Al_xIn_{1-x}P$

The room temperature compositional dependence of the Γ direct-energy gap and the X indirect-energy gap have been measured by cathodoluminescence.[27,28] The composition was determined by x-ray microprobe analysis. The results of Onton and Chicotka[27] are shown in Fig. 5.3-1. This system has the direct–indirect transition at $x = 0.44$ with $E_g = 2.33$ eV. The linear variation of the direct-energy gap shown in Fig. 5.3-1 is represented by the expression given in Table 5.3-1.

$Al_xGa_{1-x}As$

The most intensively studied III–V ternary solid solution for heterostructure lasers is $Al_xGa_{1-x}As$. Many of the properties of this system have